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(54) **WATER-REPELLENT COATING AND METHOD FOR FORMING SAME ON THE SURFACE OF LIQUID JET**

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(52) **U.S. Cl.** ........................................................ **347/20**

(58) **Field of Search** .............................. 347/20, 44, 45, 347/46, 47; 428/446

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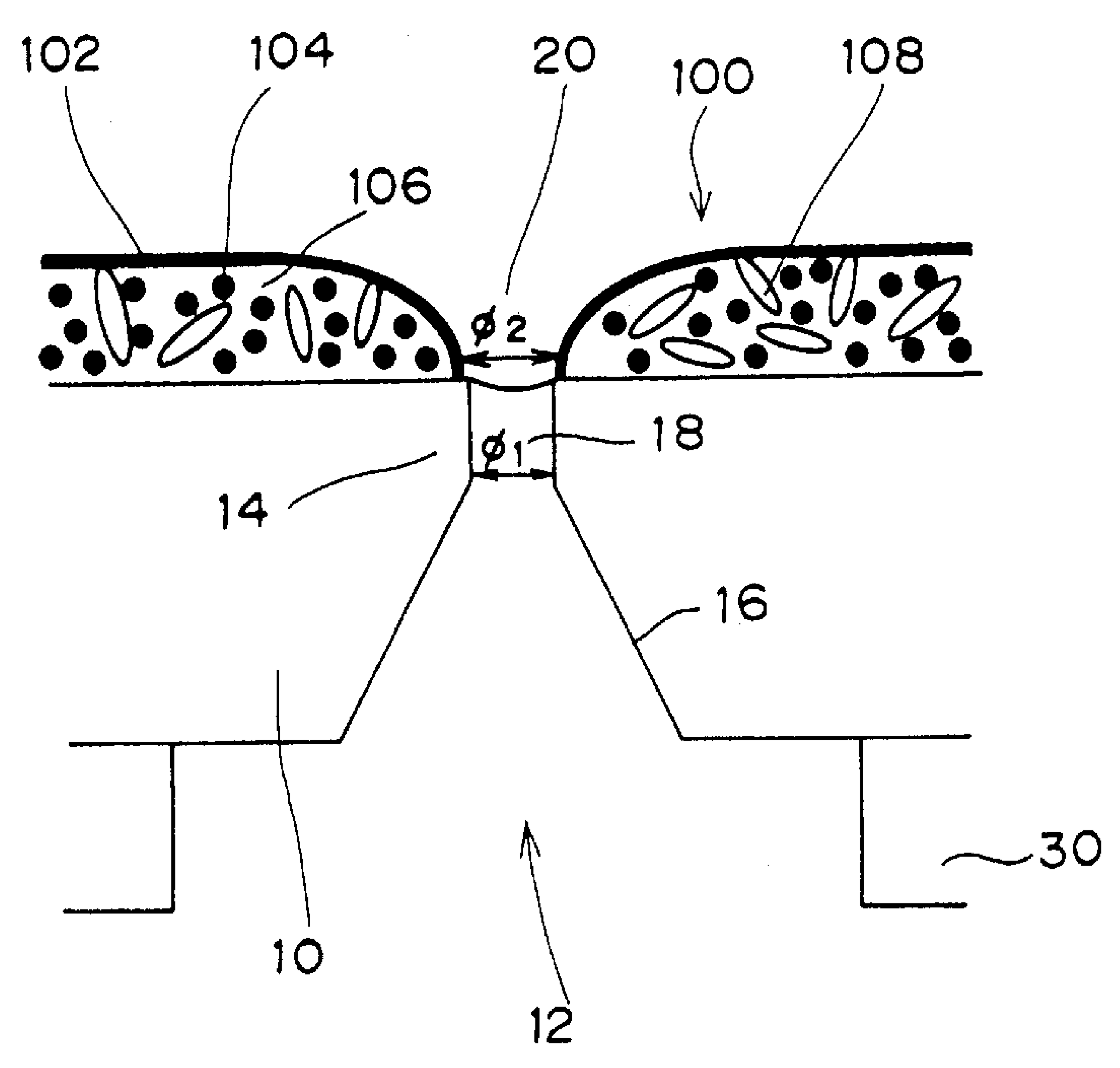
(57) **ABSTRACT**

A water-repellent coating having a higher wiping resistance against a wiper and capable of being formed by a more simplified process than was previously possible. The method of forming the water-repellent coating comprises a flat hard body and a plating-processed fluoric polymer which are formed on a nozzle plate having a nozzle as a substrate around the nozzle.

**10 Claims, 7 Drawing Sheets**



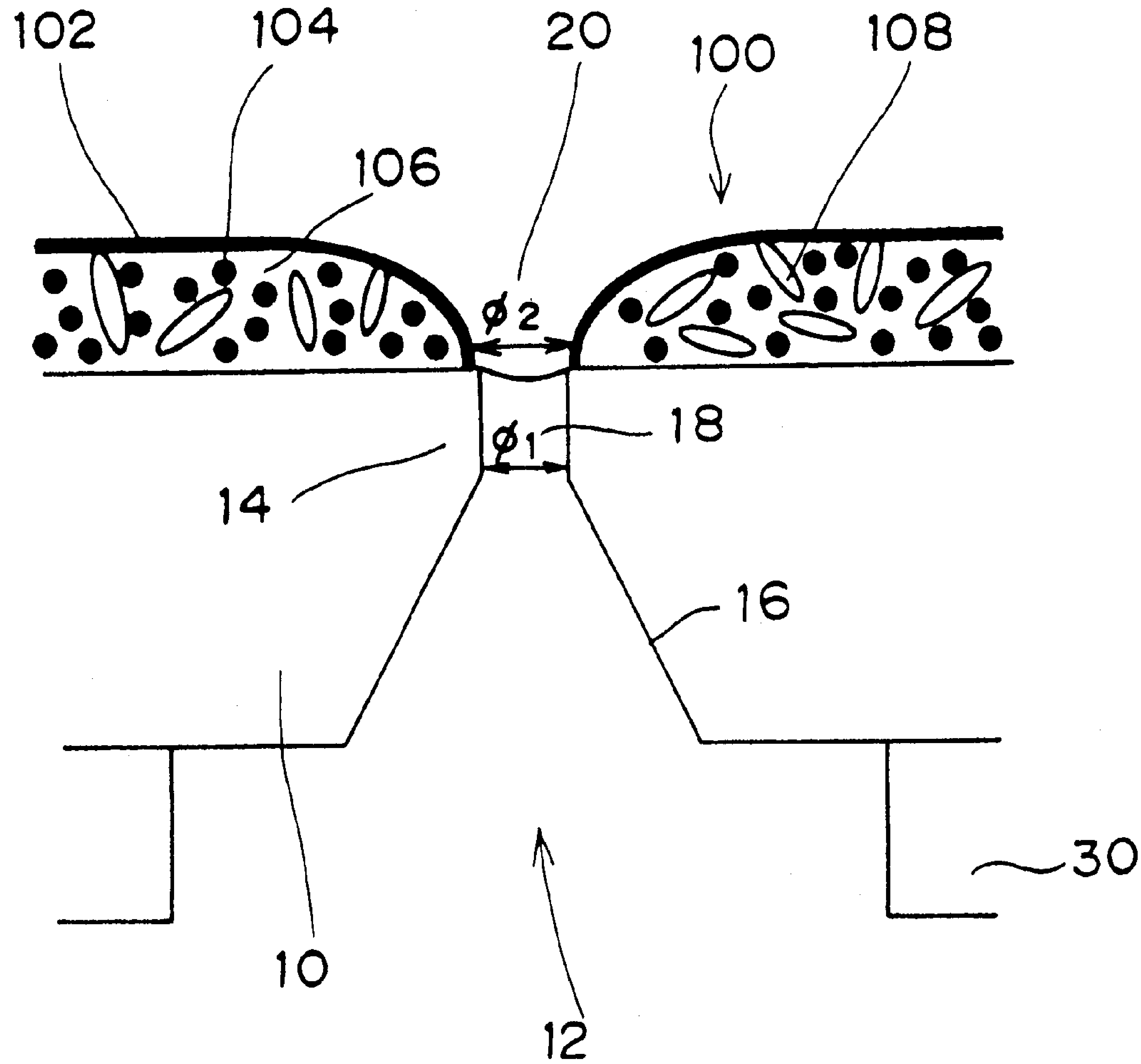



FIG. 1

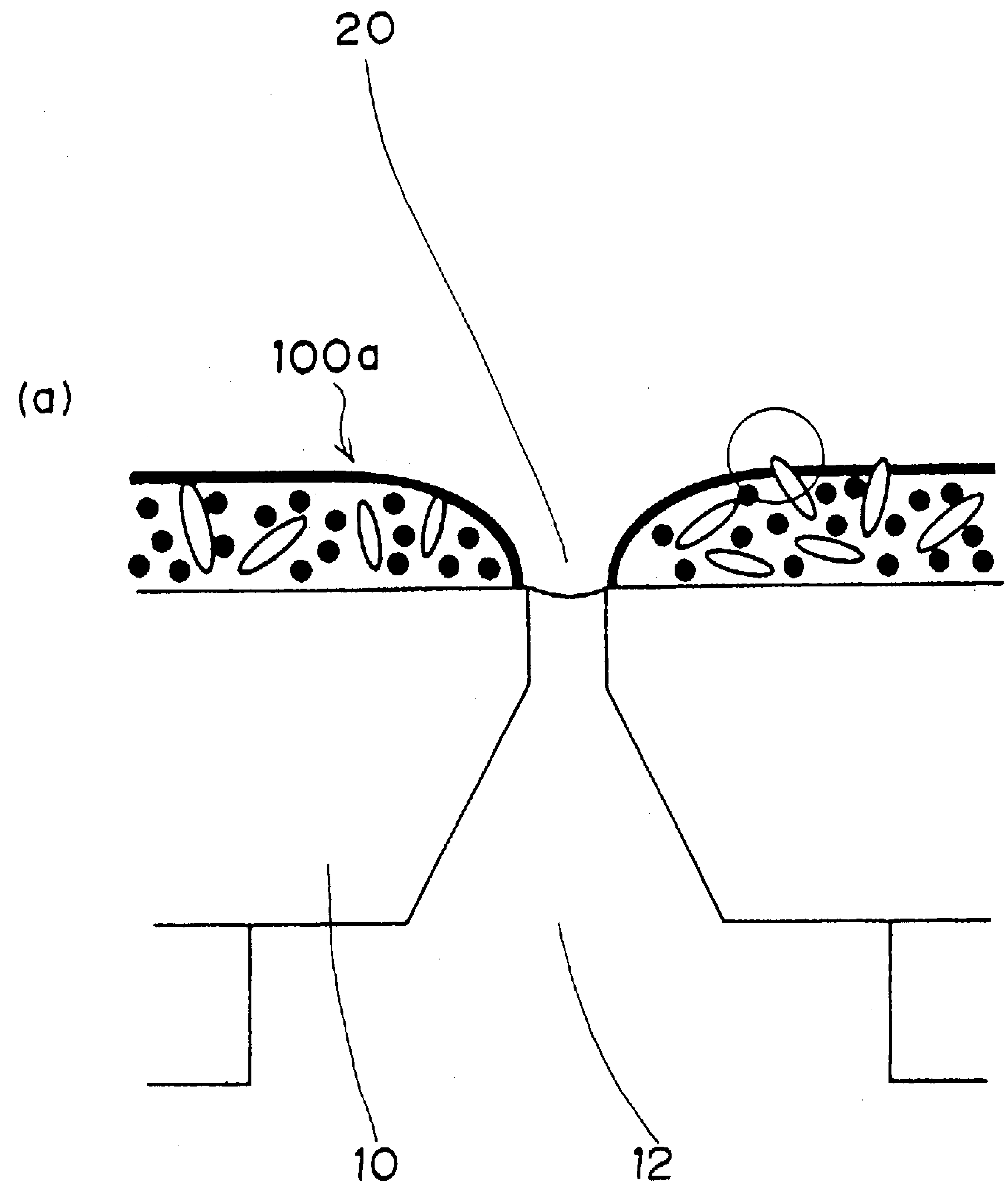



FIG. 2

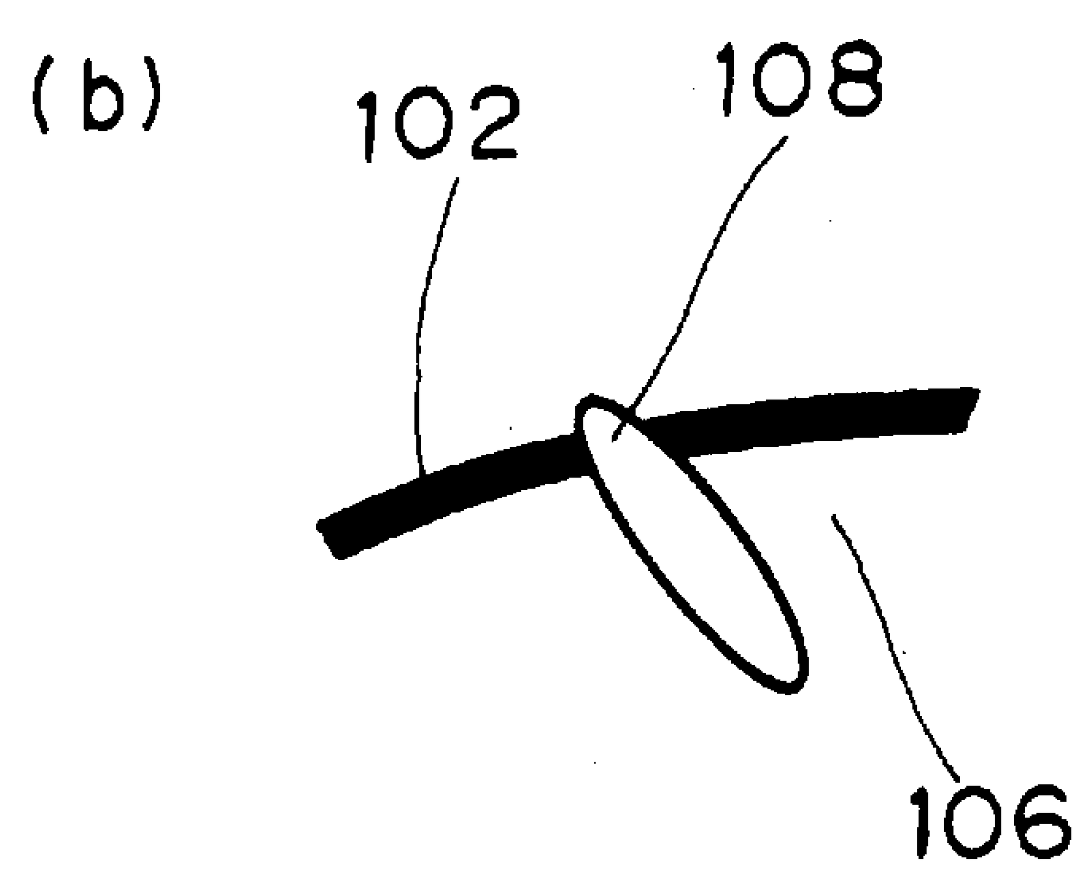



FIG. 3

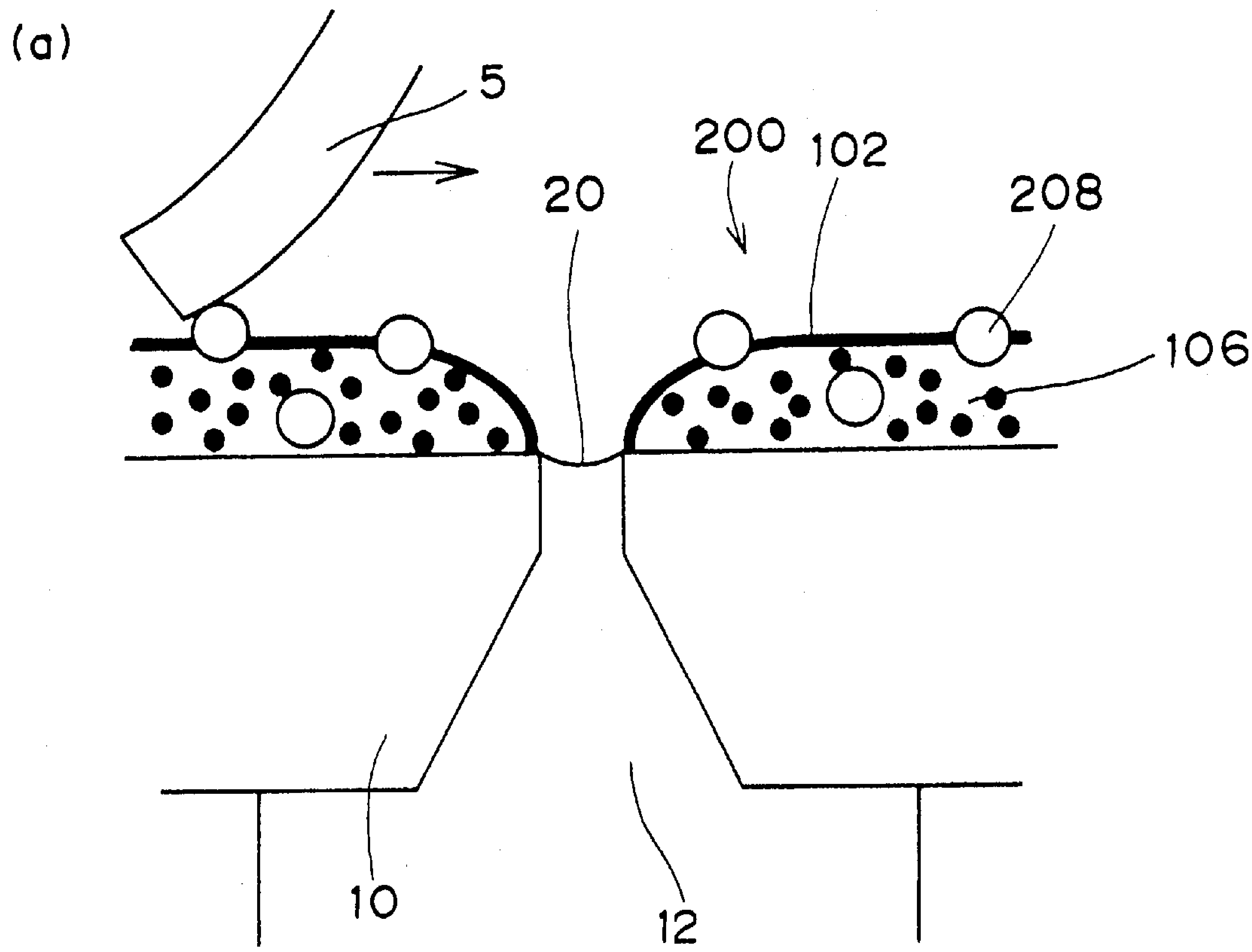



FIG. 4

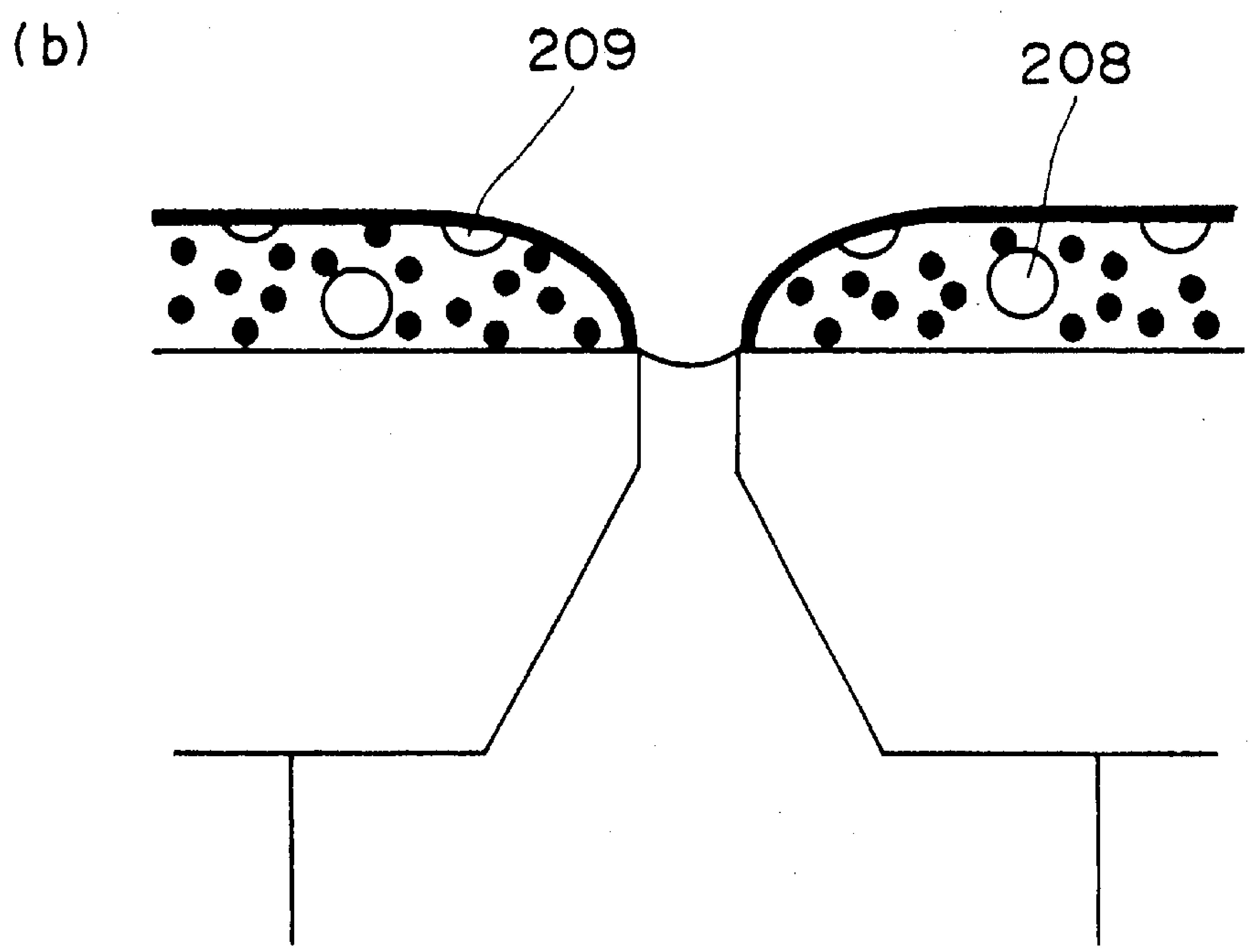



FIG. 5

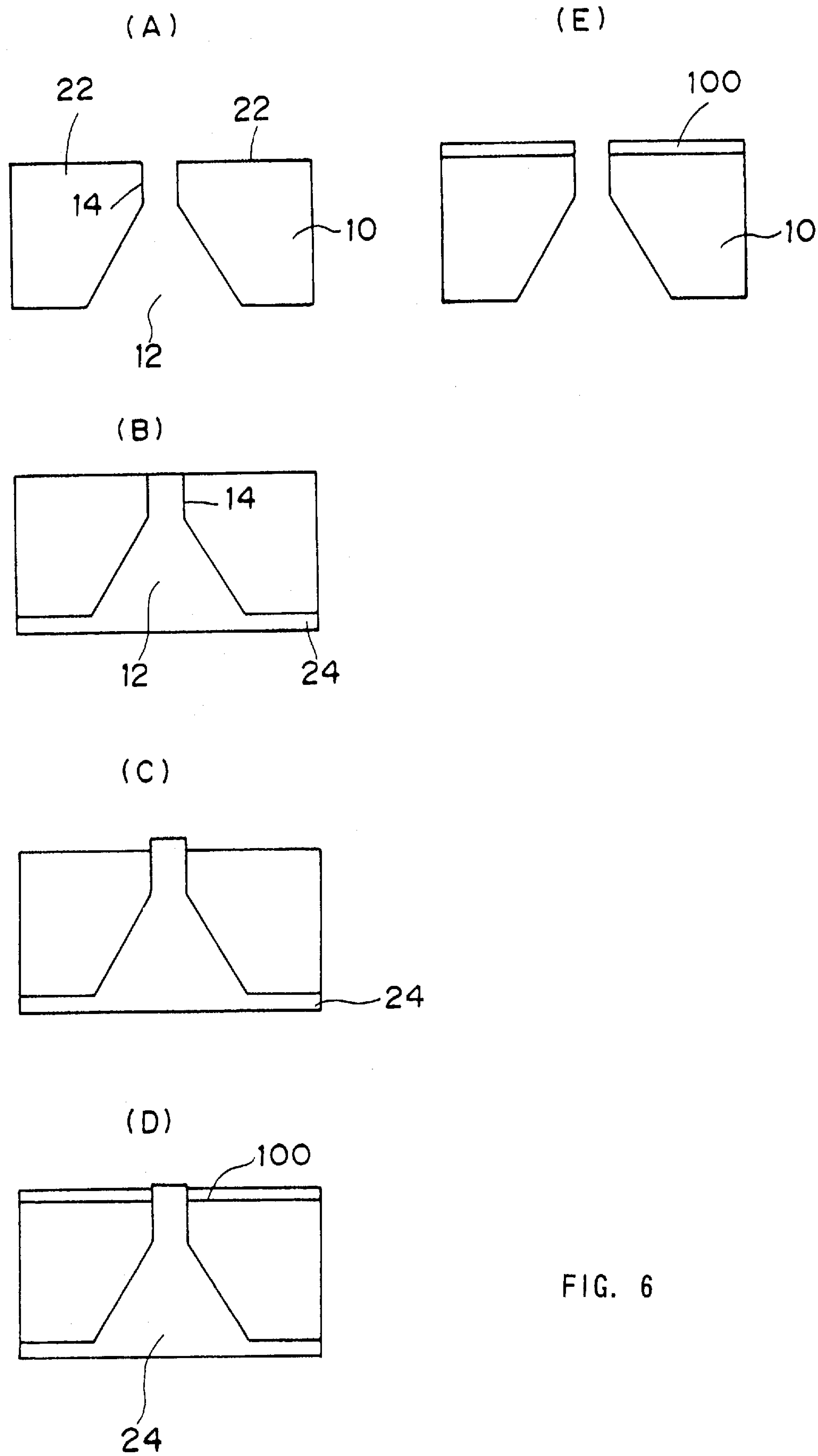



FIG. 6

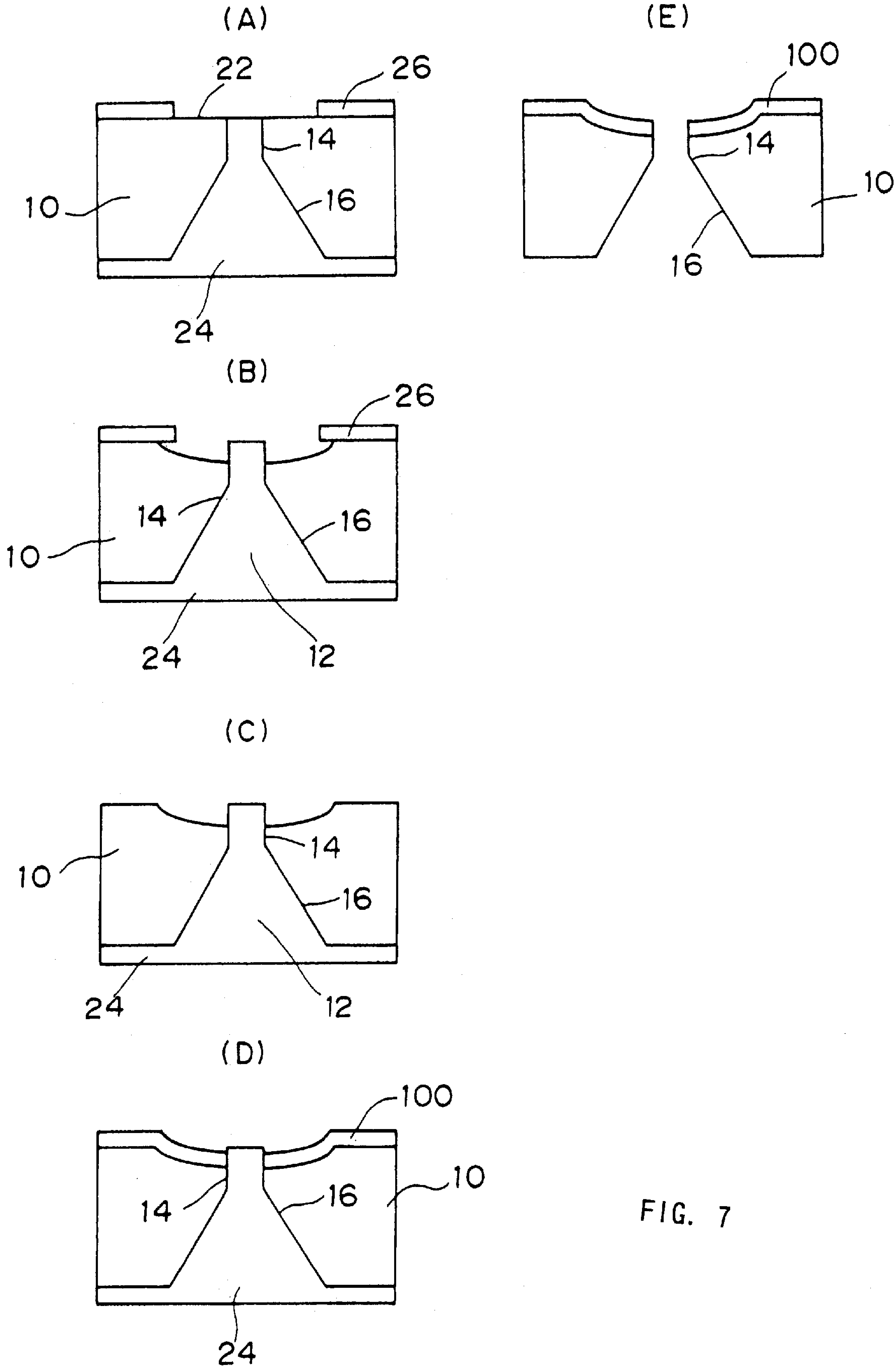
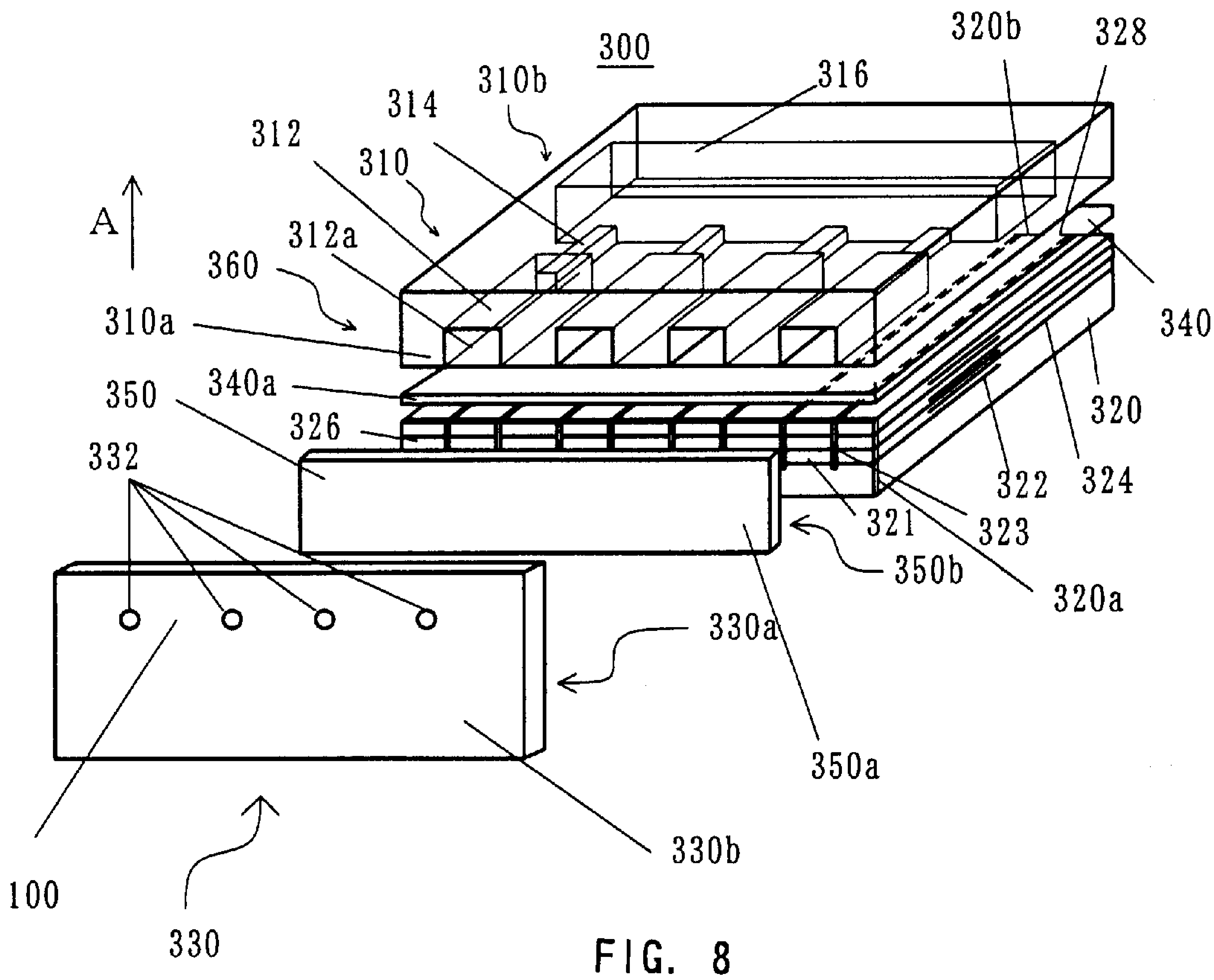

(A)
22
26
14
10
16
24
(E)
100
14
10
16
(B)
26
14
16
10
24
12
(C)
14
10
16
24
12
(D)
100
10
14
16
24

FIG. 7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320b
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316
310b
314
312
310
A
312a
360
310a
340
350
340a
320
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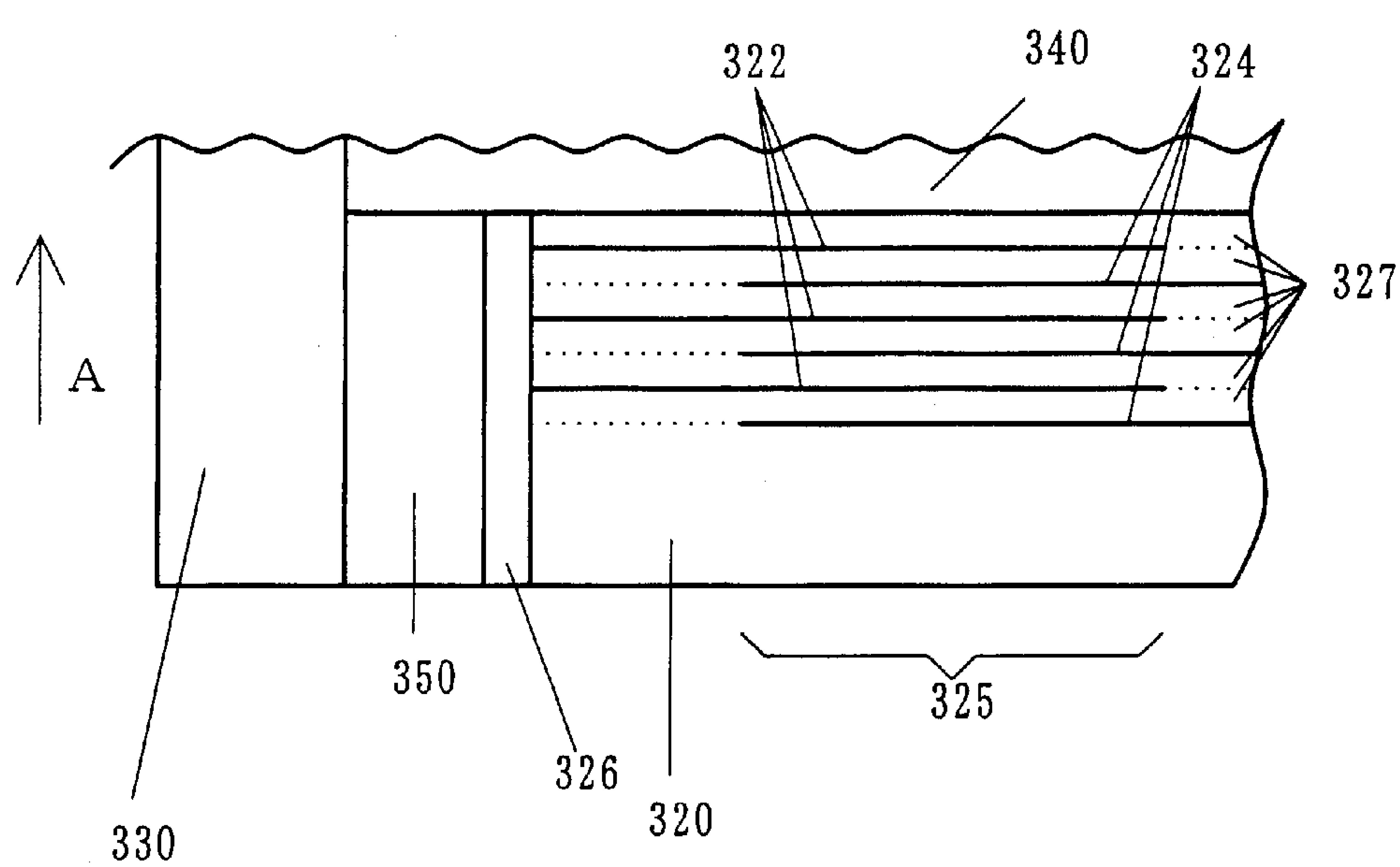
332
322
324
321
323
350b
320a
330a
350a
100
330b
330

FIG. 8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340
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A
330
350
326
320
325

FIG. 9

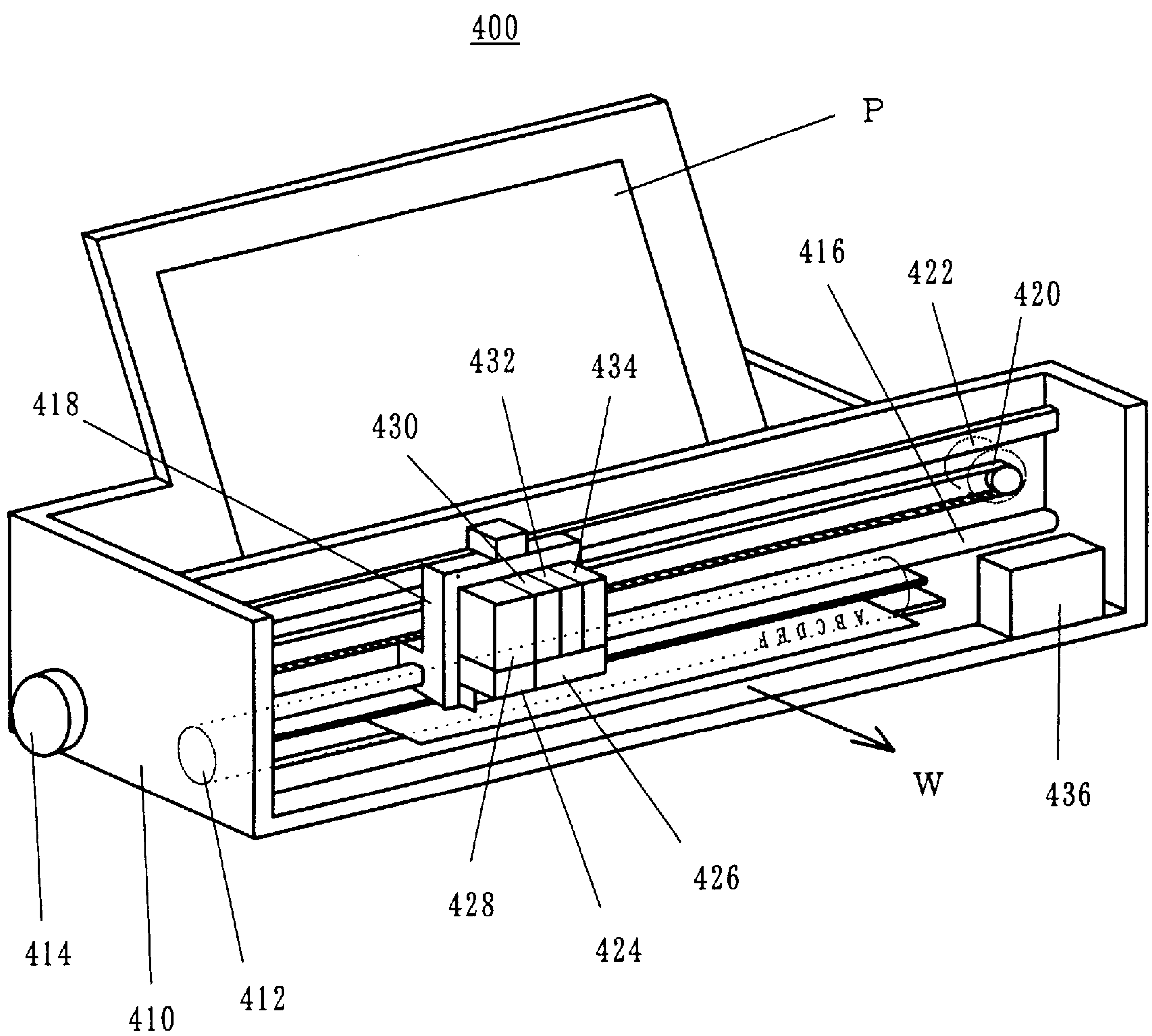


FIG. 10

# WATER-REPELLENT COATING AND METHOD FOR FORMING SAME ON THE SURFACE OF LIQUID JET

## BACKGROUND OF THE INVENTION

The present invention relates to compositions of water-repellent coatings on the surface of liquid jet nozzles and in particular a nozzle plate for an inkjet printer.

Among inkjet heads, those using a piezo-electric element have recently become more and more popular for their high energy-efficiency, etc. This kind of inkjet head typically comprises a piezo-electric element, one common ink chamber with ink supplied from outside and stored therein, a plurality of pressure chambers connected to the piezo-electric element and a nozzle plate connected to the pressure chambers so that a nozzle is connected to each pressure chamber. Each pressure chamber that is connected each corresponding ink feed path to the common ink chamber receives ink from the common ink chamber, increases an internal pressure by utilizing a deformation of the piezo-electric element, and thereby jets ink from the nozzle.

On the surface of the nozzle plate (opposite to the pressure chamber) a water-repellent coating is typically formed around the nozzle. The water-repellent coating has the following exemplary effects. First, the water-repellent coating serves to stabilize a flying direction of ink jetted from the nozzle. Without the water-repellent coating, onto the nozzle plate surface is adhered the ink spouted from the pressure chamber, the ink adhered onto the nozzle plate like this pulls the next ink jetted continuously, and thereby bends the flying direction of ink and prevents from flying straight in a desired direction. Secondly, the water-repellent coating serves to smooth a wiping process. After a printing operation is completed, the inkjet head usually undergoes a backup process that eliminates dirt from the nozzle. In the backup process, a suction pump contacts the nozzle and sucks out dirt therein, and at the same time the ink in the nozzle adheres onto the surface of the nozzle plate. Thus, the wiping process that a wiper such as rubber blade, etc. wipes ink on the nozzle surface follows. In that event, without the water-repellent coating, the ink adhered onto the nozzle plate surface after the backup process could not successfully be wiped out and would remain on the nozzle plate surface. Consequently, the subsequently flying direction of ink is bent and printing quality is adulterated with impure or diluted color if the remaining ink is different in color from the subsequently flying ink.

For the forgoing effects, it is inevitable for inkjet head to form the water-repellent coating. In addition, a conventional water-repellent coating has a fluoric polymer of high water repellency as a main ingredient.

However, the fluoric polymer is soft and less adhesive to a substrate, and thus is likely to flaw, abrasion or scratch (i.e. low wiping-resistant); therefore, its anticipated water repellency can not be continuously maintained. Accordingly, it has been desired to form a water-repellent coating that has a fluoric polymer as a main ingredient and is continuously usable about one hundred thousand times.

Conventionally, it has been suggested for example that a fluoric polymer is plated and a subsequent heating process melts the fluoric polymer adhered onto the plated surface, forms a coating and thereby improves its wiping resistance. This process, however, involves a problem that the coating, even if it is formed, is worn out shortly by a plural of frictions and its water repellency lowers. On the other hand, it has also been suggested to form a member around the



liquid jet in concave shape and avoid the fluoric coating around the nozzle from scratched by a friction. The unleveling process, however, increases its person-hours and costs.

## BRIEF SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a novel and useful water-repellent coating and method of forming the water-repellent coating in which the above disadvantages are eliminated.

More specifically, it is an exemplified object of the present invention to provide a water-repellent coating that has higher wiping resistance relative to a wiper and is formed by a more simplified process than was previously possible, and a method of forming such a water-repellent coating.

In order to achieve the above object, a print head according to claim **1** comprises a nozzle plate having a nozzle which jets ink, and a water-repellent coating that is formed on the nozzle plate as a substrate around the nozzle and comprises a hard body and a fluoric polymer formed by a plating process. According to the print head claimed in claim **1**, water repellency of the fluoric polymer works against liquid like ink, etc. jetted from the nozzle, and the hard body enhances wiping resistance of the fluoric polymer.

A print head as set forth in claim **2** that depends upon claim **1** comprises a water-repellent coating including the hard body in a flat shape. Thus, according to the print head claimed in claim **2**, the hard body is less likely to fall off than a spherical shaped one and serves to maintain wiping resistance for a long time. A print head as set forth in claim **3** that depends upon claim **1** comprises a water-repellent coating including the hard body having a major axis of 1 $\mu$m or smaller in its particle diameter. According to the print head claimed in claim **3**, the hard body having a big particle diameter never prevents a nozzle plate surface from being smoothly wiped. A print head as set forth in claims **4** and **5** that depends upon claim **1** comprises a water-repellent coating having the hard body including a boron nitride boron nitride single crystal. Therefore, according to the print head claimed in claims **4** and **5**, the boron nitride or boron carbide single crystal intrinsically having the advantage of a flat shape requires no additional process to deform the hard body into a flat shape. A print head as set forth in claims **6** and **7** that depends upon claim **1** comprises a water-repellent coating employing an electrolytic or electroless plating process as the plating process. Accordingly, the print head claimed in claims **6** and **7** has the advantage of requiring no special plating process.

A recording device as set forth in claim **8** comprises a print head and a driving device which drives the print head wherein the print head includes a nozzle plate having a nozzle which jets ink and a water-repellent coating which is formed on the nozzle plate as a substrate around the nozzle and comprises a hard body and a fluoric polymer formed by a plating process. According to the recording device claimed in claim **8**, water repellency of the fluoric polymer works against liquid like ink, etc. jetted from the nozzle, and the hard body enhances wiping resistance of the fluoric polymer.

A method of forming a water-repellent coating as set forth in claim **9** comprises the steps of forming on a nozzle plate a first resist which is open only around a nozzle of the nozzle plate, forming a first layer of a plated fluoric polymer by a first plating process via the first resist, forming a second resist, adding a hard body to a first layer by a second plating process, and removing the first and second resists. According to the method of forming a water-repellent coating claimed in this claim, the hard body is allowed to protrude from the water-repellent coating surface because the water-repellent coating is formed on the nozzle plate as a substrate. A method claimed in claim **10** that depends on claim **9** further comprises the step of heating the water-repellent coating until its water repellency becomes enough to make a contact angle of ink containing 10% of alcohol 60 degrees or larger. By the heat treatment, the fluoric polymer melts and taking in the additive hard body.

Other objects and further features of the present invention will become readily apparent from the following description and accompanying drawings.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic sectional view for explaining a composition of a water-repellent coating of the present invention.

FIG. **2** is a schematic sectional view illustrating a variation of the water-repellent coating shown in FIG. **1** or a state after a predetermined period of use.

FIG. **3** is an enlarged view of a portion circled in a solid line in FIG. **2**.

FIG. **4** is an aschematic sectional view for explaining a composition of a water-repellent coating having a spherical hard body relative to the water-repellent coating in FIG. **1** having a flat hard body.

FIG. **5** is a schematic sectional view for explaining a state in which the spherical hard body in FIG. **4** is fallen down.

FIG. **6**A–FIG. **6**E are flow sectional diagrams for explaining one example of a method of forming the water-repellent coating shown in FIG. **1**.

FIG. **7**A–FIG. **7**E are flow sectional diagrams for explaining another example of a method of forming the water-repellent coating shown in FIG. **1**.

FIG. **8** is an exploded perspective view of a completed inkjet head **300**.

FIG. **9** is a partially enlarged side view of an inkjet head **300**.

FIG. **10** is a perspective overview of a recording device according to the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. **1** to **3** inclusive, a description will be given of a water-repellent coating **100** according to the present invention. FIG. **1** is a schematic sectional view for explaining a composition of a water-repellent coating **100** of the present invention. FIG. **2** is a schematic sectional view of a water-repellent coating **100***a* showing an exemplified variation or a state after a predetermined period of use. FIG. **3** is an enlarged view of a portion circled in a solid line in FIG. **2**. In each drawing, those elements designated by the same reference numeral denote the same elements, and a duplicate description thereof will be omitted. Those elements designated by the same reference numeral with a variety of alphabetical letters attached thereto denote the same kinds of elements but are distinguished from each other by alphabets and are comprehensively designated by simple reference numerals.

The water-repellent coatings **100** and **100***a* are, for example, 1 through 2 $\mu$m thick and are formed around a nozzle **12** on the surface of a nozzle plate **10**. FIG. **1** is an enlarged sectional view around a nozzle (hole) **12** applicable to a print head **300** which will be described later (e.g. piezo-type inkjet head and a bubble jet-type inkjet head). The nozzle plate **10** comprises the nozzles **12** each having a straight portion **14** and a taper portion **16**, to the number corresponding to a predetermined resolution. The nozzle **12** does not necessarily include both of the straight portion **14** and the taper portion **16** but may include only one of them. A portion defined by the straight portion **14** is an opening portion **18** of the nozzle **12** where a meniscus **20** of ink is formed. The nozzle plate **10** is connected to a pressure chamber plate **30**, and the pressure chamber plate **30** is provided with an ink chamber as will be described later.

The water-repellent coatings **100** and **100***a* comprise a fluoroplastic coating **102**, a fluoroplastic particle **104**, a nickel base **106** and a flat hard body **108**. The water-repellent coating **100** shown in FIG. **1** is different from the water-repellent coating **100***a* shown in FIG. **2** in whether the flat hard body **108** is partially protruded from the fluoroplastic coating **102**.

The water-repellent coatings **100** and **100***a* are characteristically formed on the nozzle plate **10** as a substrate. Therefore, this invention does not adopt such a method, for example, that the water-repellent coating and the nozzle plate **10** are formed in this sequence on a plane and then the plane is removed. Because this method makes the hard body **108** unable to protrude from the fluoroplastic coating **102** as shown in FIG. **2**. A projection structure of the hard body **108** as shown in FIG. **2** is suitable for preventing the fluoroplastic coating **102** from being scratched by a friction of a wiping blade (wiper) and making it possible to maintain ink water repellency for a long period.

For the fluoroplastic coating **102** and the fluoroplastic particle **104**, tetrafluoroethylene resins, tetrafluoroethylene-hexafluoropropylene copolymerization resins, trifluoroethylene chloride resins, fluorovinylidene resins, fluorovinyl resins, PTFE, FEP, ETFE, PFA, PCTFE and PVDF are usable either singly or in the form of a mixture of two or more of them. Their average particle diameters should preferably be less than 150 $\mu$m and in particular ranging from 0.05 to 20 $\mu$m. In addition to the above fluoroplastic particles, as needed, other inorganic or organic precipitation polymer particulates may be formed together.

The nickel base **106** as a plating coating is added to improve adhesion. Other than nickel may be employed copper, silver, zinc, tin, cobalt and such nickel alloys as a nickel-cobalt alloy, a nickel-phosphorus alloy and a nickel-boron alloy, etc. The plating coating can be formed, for instance, by using the electrolytic plating solution or electroless plating solution in which PFA is suspended. The electrolytic plating solutions according to a variety of metal plating coatings to be deposited may be selected from an electrolytic nickel plating solution such as the Watts bath, a chloride-rich bath, a nickel sulfamate bath and a nickel borofluoride bath, etc.; an electrolytic cobalt plating solution such as a cobalt sulfate bath and a cobalt chloride bath, etc.; an electrolytic copper plating solution such as a copper sulfate bath and a copper borofluoride bath, etc.; an electrolytic lead/tin plating solution such as a lead sulfate bath, a tin sulfate bath and a lead borofluoride bath, etc. It is however preferable to employ a sulfamic acid bath having a sulfamic acid ion content of more than 0.5 mol, more desirably more than 0.8 mol especially in the light of their properties that form more precipitation and resist agitation. The electroless plating solutions may be selected from an electroless nickel plating solution, an electroless cobalt plating solution and an electroless copper plating solution, etc. using a boron compound such as a hypophosphate and a dimethyl borazon, etc. as a reducing agent.

The hard body **108** has a higher hardness than a fluoric polymer and a flat shape. The hard body **108** should preferably be as water-repellent, wiping-resistant and frictionless as possible. Even though the hard body **108** has low water repellency, a heat treatment as will be described later melts the fluoric polymer, covers the hard body **108**, and thereby maintains the water repellency. The hard body **108** is added so as to promote the wiping resistance of the fluoric polymer against the wiper. Its flat shape aims at enhancing an anchor effect into the plating coating. A more specific description is now given to the enhanced anchor effect. To illustrate, suppose that a spherical hard body **208** (e.g. having more than 1 $\mu$m in diameter) is dispersed in the water-repellent coating **200** (e.g. of about 1 $\mu$m in thickness), as shown in FIG. **4**. If the water-repellent coating **200** is wiped on its surface by a wiper **5**, the spherical hard body **208** other than having more than half of its diameter embedded in the water-repellent coating **200** is fallen down as shown in FIG. **5**, so that the wiping resistance of the water-repellent coating lowers to such a level as that of the water-repellent coating having no hard body **208**. In FIG. **5**, a mark left by the hard body **208** is indicated with **209**.

As the hard body **108**, are usable, for example, BN (boron nitride), boron carbide, silicon carbide, titanium carbide, tungsten carbide, graphite fluoride, alumina, glass and ceramics, etc. The boron nitride and boron carbide are suitable for the water-repellent coating of this invention in that they are dealt with in a single crystal and the single crystal is not spherical in crystal structure (the boron nitride is flat). Particularly, the boron nitride, which is used for reducing friction of a bearing, is suitable for improving sliding properties of the electroless nickel coating and increasing strength of the fluoroplastic coating **108**. When the alumina, glass, ceramics are used, they should be deformed in a flat shape. BN added for this is, for example, some 5 g/l or 10 g/l, preferably 20 g/l.

Since the additive hard body **108** is less water-repellent than the fluoric polymer, the water-repellent surface should be covered as widely with the fluoric polymer as possible. Therefore, it is necessary to increase a water-repellent portion of liquid contact surface by heating and melting the fluoric polymer after plated so as to taking in the additive.

Referring now to FIG. **6**A–FIG. **6**E, a description will be given of a method of manufacturing a nozzle plate with a water-repellent coating as shown in FIGS. **1** and **2**. Hereupon, FIG. **6**A–FIG. **6**E are flow sectional diagrams for explaining one exemplified method of the water-repellent coating **100** shown in FIG. **1** or the water-repellent coating **100***a* shown in FIG. **2**. First, as shown in FIG. **6**(A), a nozzle plate substrate **10** of a stainless steel (SUS316) plate of 100 $\mu$m through 300 $\mu$m thickness is processed by stamping, etching, electrical discharge machining and laser machining, etc. and is provided with a nozzle **12**. To illustrate, assume that a conic nozzle **12** is made by stamping, a straight portion **14** being 40 $\mu$m thick and 20 $\mu$m length, and a taper portion **16** has a taper angle of 20 degrees. A nozzle plate surface **22** is roughly ground to remove burrs left by the processing but the burrs are not completely removed.

Next, as shown in FIG. **6**(B), corrosion-resistant polymer resin as a resist is filled in the processed nozzle **12**. A photosensitive liquid resist is usable as a resin member in contemplation of its subsequent removal and its machinability. This example utilizes a dry film resist (DFR) **24** of a curing acrylic resin. The DFR **24** becomes a viscid liquid by adding a sufficient heat and is easily filled in the nozzle **12**. Further, in terms of removal, water soluble DFR which may be easily removed with alkaline water solution is available.

As shown in FIG. **6**(C), the nozzle plate surface **22** is drenched in a stainless etching solution and etched. On the



nozzle plate surface **22** there exist burrs left by the processing or rough grinding of the nozzle **12**, but can easily be removed by etching process. This makes it possible to omit a final finishing grinding step in processing the nozzle plate **10**, and enables a cost-reduction. In addition, a chemical grinding means, if used, may reduce a mechanical stress applied to the nozzle substrate **10** and may improve processing accuracy. The etching depth is 10 $\mu$m and the length of straight portion **14** is 10 $\mu$m.

Thereafter, a water washing, an electrolytic defatting, a water washing, an acid washing and a strike Ni plating are processed, and a water-repellent coating **100** is formed on the nozzle plate surface **22** with a Ni precipitation plating as shown in FIG. **6**(D). The water-repellent coating **100** has the thickness not exceeding the height of the protruded DFR **24**. Then, the nozzle plate **10** is drenched in an alkaline water solution, the DFR **24** is removed as shown in FIG. **6**(E), and the nozzle plate **10** with a water-repellent coating **100** becomes completed. When materials as having difficulty in being etched, such as ceramics, glass, etc. are used as the nozzle plate **10**, the grinding process (FIG. **6**(C)) may be substituted by a physical means using a sandblast. In that event, a sandblast-resistant DFR **24** that includes a polyurethane resin other than an acryl resin as usual ingredients (e.g. BF series made by Tokyo Ohka Kogyo Co., Ltd.) may be employed. The physical grinding means is also applicable to a nozzle plate substrate **10** made of metal.

Like this, the water-repellent coating **100** on the nozzle plate surface **22** by Ni precipitation plating is formed along a projected portion of DFR **24**, preventing dropping into the nozzle **12**, and maintains the size accuracy of the nozzle **12** and the water-repellent coating **100**. For example, in FIG. **1**, the water-repellent coating **100** is formed so that it permits dropping by making its diameter $\phi_2$ within 3% range of the diameter $\phi_1$ of an opening **18**. This 3% difference is for the purpose of arranging the opening of the water-repellent coating **100** and the opening **18** of the nozzle plate on almost the same side. This arrangement can prevent a deviation of ink dots, stabilize flying ink direction and provide high quality images.

Referring next to FIG. **7**A–FIG. **7**E, a description will be given of another method of manufacturing the nozzle plate **10** having the water-repellent coating **100**. The process shown in FIG. **7**A–FIG. **7**E, is a variation of the process of FIG. **6**(C) and those that follow, and it is to be construed that the process indicated in FIG. **7**(A) follows the process indicated in FIG. **6**(B). As shown in FIG. **7**(A), on the nozzle plate surface **22** is formed a liquid resist or a DFR coating **26** capable of alkaline development and removal, and then the exposure and development with a mask pattern eliminate coatings around the opening **18** on the nozzle plate surface **22**. Next, as shown in FIG. **7**(B), the nozzle plate substrate **10** is drenched in an etching solution and the surface of the opening the coating **26** is ground. The etching depth can be adjusted by altering etching conditions. By adjusting the depth, the length of the straight portion **14** and the projection amount of the DFR **24** are adjusted.

As shown in FIG. **7**(C), the coating **26** is removed with strong alkaline solution. In this case, the DFR **24**, which is an alkaline-resistant resist, is not eliminated and remains. After that, a water washing, an acid washing, an electrolytic defatting, a water washing and a strike Ni plating are processed. Subsequently, as shown in FIG. **7**(D), Ni precipitation plating is processed on the nozzle plate surface **22** and the water-repellent coating **100** is formed. The coating thickness is so adjusted as does not exceed the projection amount of the DFR **24**. Thereafter, as shown in FIG. **7**(E), the DFR **24** are removed and eliminated with solution development-type resist removal solution.

The above manufacturing method can also provide a nozzle plate **10** having an accurate sized water-repellent coating **100**, as in FIG. **6**. This method, particularly as using DFR **24** as a resist member, only necessitates a heating process where an exposure process may be omitted, and is applicable at one step from the back of the nozzle plate substrate **10**, whereby reducing manufacturing costs.

Description will be given of a method of manufacturing a water-repellent coating **100** shown in FIG. **1** or a water-repellent coating **100***a* shown in FIG. **2**. First, in order to form a water-repellent plating coating only on the surface of the nozzle plate **10**, other portions are masked so as not to adhere the coating. In this step, the nozzle plate **10** as a substrate is laminated at the side on which a pressure chamber **30** is formed with an alkaline development-type dry film (this exemplified embodiment utilizes α-450 made by Tokyo Ohka Kogyo Co., Ltd.) on conditions of 120° C., 2.5 kgf/cm, 0.5 m/min. This allows the dry film to break in to the taper portion **16** and the straight portion **14** of the nozzle **12**. Moreover, the resist flows out of ink jet opening of the nozzle, covering a portion around the edge of the nozzle opening of a width of 1 μm, and then the resist is hardened by a double-sided exposure.

On the other hand, in order to form a water-repellent coating with a single crystal BN (boron nitride) added thereto, prepare a fluoroplastic containing Ni plating solution (made by Hikifune Co., Ltd.) to which a BN with longitudinal particle size of 1 μm or smaller (particles of more than 1 μm being crushed to this size) is added at the rate of 20 g/l and coat a water-repellent plating to the nozzle plate **10** masked as described above.

The nozzle plate **10**, made of stainless steel (SUS430), is drenched in 10% hydrochloric acid for three minutes, washed in water to remove an oxidized coating and is strike Ni plated to improve its plating adhesion.

The specification of the strike Ni plating is as follows.

| | | |
|---|---|---|
| (1) | Bath composition | |
| | nickel chloride ($NiCl2.\ 6H_2O$) | 220 g/l |
| | hydrochloric acid (HCl 35%) | 45 g/l |
| (2) | Temperature | room temperature |
| (3) | Electrode | |
| | titanium basket (150 × 30 × 250 mm) | |
| | electrolytic nickel (ø 1B × 10 mm) | |
| (4) | Current density | 2 $A/dm^2$ |

After one-minute plating by using this strike Ni plating solution, the nozzle substrate is drenched in a water-washing bath and immediately commences a water-repellent plating process. The specification of the water-repellent plating is as follows.

| | | |
|---|---|---|
| (1) | Solution composition | |
| | nickel sulfamate | 420 through 480 g/l |
| | nickel chloride | 40 through 50 g/l |
| | boric acid | 30 through 40 g/l |
| | PTFE | 40 through 50 g/l |
| | BN | 20 g/l |
| | PH | 4.0 through 4.4 |

-continued

| | | |
|---|---|---|
| (2) | Temperature | 42° C. |
| (3) | Electrode | |
| | titanium basket (150 × 30 × 250 mm) | |
| | electrolytic nickel (ø 1B × 10 mm) | |
| | diaphragm | |
| (4) | Current density | 2 $A/dm^2$ |

The nozzle substrate is plated for three minutes by using this water-repellent plating solution. After washed in water, it is drenched in a NaOH (3 wt %) solution, removes a resist, and then after water washing and drying processes, makes PTFE into a coating adhered as a plating by a heating process at 350° C. for thirty minutes. The plated coating, as shown in a photograph attached herewith, has BN particles scattered thereon, whereby preventing a convex portion of the BN particles from being scratched even though an outermost fluoric coating is scratched by friction and abrasion of a wiper (rubber blade), so that a water-repellent effect can be maintained.

Referring next to FIGS. **8** and **9**, a description will be given of an inkjet head **300** of the present invention. FIG. **8** is an exploded view of the completed inkjet head **300** and FIG. **9** is a partially enlarged side view of the inkjet head **300**. As seen from FIG. **8**, the inkjet head **300** of the present invention comprises a pressure chamber plate **310**, a piezo-electric element **320**, a nozzle plate **330**, a resin film **340** and a protective layer **350**. The nozzle plate **330** corresponds to the nozzle plate **10** shown in FIG. **1** and the pressure chamber plate **310** corresponds to the pressure chamber plate **30** shown in FIG. **1**. The pressure chamber plate **310**, the resin film **340** and the protective layer **350** are aligned with each other at a nozzle connection surface **360** that is a surface to which a surface **330***a* of the nozzle plate **330** is connected. In other words, the front surface **310***a* of the pressure chamber plate **310**, a front surface **340***a* of the resin film **340** and a front surface **350***a* of the protective layer **350** form the flat nozzle connection surface **360**.

The pressure-chamber plate **310** has the desired number (four in FIG. **8** for description purposes) of pressure chambers **312** and ink introduction channels **314** and a common ink chamber **316** in an approximately rectangular parallelepiped glass plate. Each pressure chamber **312** receives and accommodates ink, and jets the ink from a nozzle **332** connected to an opening **312***a* as its internal pressure increases. The internal pressure changes according as the piezo-electric block **321** just under the pressure chamber **312** deforms, as will be described later. The pressure chamber **312** is formed as an approximately rectangular parallelepiped space by a concave groove on the pressure chamber plate **310** and the elastically deformable resin film **340**. The common ink chamber **316** supplies ink to each pressure chamber **312** via the corresponding ink introduction channel **314**. A bottom of the common ink chamber **316** is defined by the resin film **340** so as to absorb sudden internal pressure changes, and connected to an ink feed device (not shown) at a side surface **310***b* of the pressure chamber plate **310**. The common ink chamber **316** supplies a necessary amount of ink to the pressure chamber **312** via the ink introduction channel **314** when the pressure chamber **312** returns to the original state after the chamber **312** contracts, receives pressure and jets ink.

The resin film **340** defines one surface of each of the pressure chambers **312**, the common ink chamber **316** and each of the ink introduction channels **314**, and serves to transmit a deformation of each piezo-electric block **321** which will be described later to the corresponding pressure chamber **312** and to prevent ink in the pressure chamber **312** from penetrating into grooves **323** in the piezo-electric element **320**. The resin film **340** is, for example, approximately 16 $\mu$m thick and the order of Gpa adhesive. The resin film **340**, which is a member that forms one surface of the pressure chamber **312**, may be replaced with an elastic metal thin film.

The piezo-electric element **320** has layered structure having a plurality of (four in FIG. **1** for description purposes) piezo-electric blocks **321** which are divided by parallel grooves **323** which extend from a front surface **320***a* to a rear surface **320***b*. Internal electrodes **322** and **324** are provided between layers of piezoelectric blocks **321**, and the internal electrode **322** is connected to an external electrode **326** and the internal electrode **324** is connected to an external electrode **328**. FIG. **8** shows only one external electrode **328** for illustration purposes. As shown in FIG. **9**, an active area **325** is a portion where the internal electrodes **322** and **324** overlap each other in direction A, and each piezo-electric block **321** deforms in the active area **325**. The length of each active area **325** is adjustable depending upon a pressure to be applied to the pressure chamber **312**. Since the active area **325** is spaced at a predetermined distance from the nozzle connection surface **360**, even when the piezo-electric blocks **321** deform, such deformation does not affect the adhesion between the piezo-electric element **320** and the protective layer **350** at the nozzle connection surface **360**.

The external electrode **326** is an electrode layer that is evaporated onto an entire surface of the front surface **320***a* of the piezo-electric element **320**, and an external electrode commonly used for all the piezo-electric blocks **321**. The external electrode **326** is grounded. On the contrary, the external electrode **328**, which is provided on the rear surface **320***b* of the piezo-electric element **320**, is however an electrode layer which is not evaporated onto an entire surface of the rear surface **320***b* and is independently provided only on a portion corresponding to each piezo-electric block **321**. The external electrode **328** has no potential unless electrified, but may apply a positive voltage to the internal electrode **324**.

Due to such a structure, each piezo-electric block **321** of the piezo-electric element **320** does not deform when no voltage is applied to the external electrode **328**, since both potentials of the internal electrodes **322** and **324** remain zero. On the other hand, when a voltage is applied from the external electrode **328**, each piezo-electric block **321** may deform in the direction A (longitudinal direction) in FIG. **8**, independent of the other piezo-electric blocks **321**. In other words, the direction A is the polarization direction of the piezo-electric blocks **321**. When the electrification to the external electrode **328** stops, that is, when the piezo-electric element **320** is discharged, the corresponding piezo-electric block **321** returns to the original state.

The piezo-electric element **320** of this embodiment is made of a plurality of green sheets **327**. Each green sheet **327** is blended with solvents such as a ceramic powder, etc., kneaded into a paste and then formed to be a thin film having a thickness of about 50 $\mu$m by a doctor blade.

Among these green sheets, a pattern of the internal electrode **322** is printed and formed onto one surface of each of three green sheets, a pattern of the internal electrode **324** is printed and formed onto one surface of each of another three green sheets, and no internal electrode is formed onto the remaining sheets. Each of the internal electrodes **322** and **324** is printed by blending alloy powder of silver and palladium with a solvent into a paste to apply for its pattern formation.

Then, the three sheets including the internal electrode **322** and the three sheets including the internal electrode **324** are alternately stuck together, and thereafter the remaining six sheets are also stuck together. Thereby, the layered structure of the piezo-electric element **320** is formed as shown in FIG. **9**. The green sheets that include none of the internal electrode **322** or **324** are stuck at a lower portion (in FIG. **9**) of the piezo-electric element **320** and form a base part. These layered green sheets are sintered. Then, at least six sheets are partially cut by a diamond cutter from the front surface **320***a* to the rear surface **320***b*, whereby a plurality of the piezo-electric blocks **321** divided by the grooves **323** is formed. Lastly, the external electrodes **326** and **328** are formed by vacuum evaporation at the front surface **320***a* and the rear surface **320***b*. It is possible to form the grooves **323** before sintering. The completed piezo-electric element **320** is submitted to a characteristic test by applying a voltage to the external electrodes **326** and **328**, and malfunctioning ones are eliminated.

The inkjet head **300** shown in FIG. **8** further comprises the protective layer **350**. The protective layer has useful effects as will be explained later, but there is a choice whether the protective layer is provided.

The protective layer **350** is a thermosetting epoxy adhesive member having an approximately rectangular parallelepiped shape with a thickness of about 50 $\mu$m, and connected via a surface **350***b* to the front surface **320***a* of the piezo-electric element **320** (external electrode **326**). The materials for the protective layer **350**, however, are not limited to this type. For example, an epoxy filler member, an acrylic resin, a polyethylene resin or the like are usable for the protective layer **350**. The protective layer **350** in the actual inkjet head **300** does not have a rectangular parallelepiped shape in the strict sense of the term, and an interface between the protective layer **350** and the piezo-electric element **320** is not clear or simple as shown in FIGS. **8** and **9** by the external electrode **326** and the surface **350***b*. The protective layer **350** partially penetrates through the grooves **323** into the piezo-electric element **320** before heatedly solidifying. Accordingly, it is preferable that the protective layer **350** is made of insulators so as to prevent a short circuit of the internal electrodes **322** and **324**. The protective layer **350** of this embodiment is applied to the piezo-electric element **320** (external electrode **326**) all over the front surface **320***a*, but may, if necessary, be applied partially.

The protective layer **350** spaces the piezo-electric element **320** about 50 $\mu$m apart from the nozzle connection surface **360**. If ink leaked from the pressure chamber **12** and penetrated into the piezo-electric element **320**, the ink would penetrate into the piezo-electric element **320** mainly along the nozzle connection surface **360**. However, the protective layer **350** spaces from the nozzle connection surface **360** the piezo-electric element which has been conventionally located on the nozzle connection surface **360**, and thereby prevents the ink from penetrating into the piezo-electric element **320** and short-circuiting the internal electrodes **322** and **324**.

Moreover, the protective layer **350** shields the grooves **323**. If ink leaked and penetrated into the piezo-electric element **320**, the ink would penetrate mainly from an opening **312***a* of the pressure chamber **312**, running along the nozzle connection surface **360**, through the grooves **323** into the piezo-electric element **320**. However, the protective layer **350** does shield the grooves **323** against or from the nozzle connection surface **360**, and thereby prevents the ink from penetrating into the groove **323** from somewhere in the neighborhood of the front surface **320***a* of the piezo-electric element **320** and short-circuiting the internal electrodes **322** and **324**.

In addition, the protective layer **350** also has the effect of protecting the piezo-electric element **320** from being destroyed by polishing in a polishing process for forming the nozzle connection surface **320***a* among various steps of manufacturing the inkjet head. Consequently, the polishing process never causes any removing crack and chip-off of the piezo-electric element **320**. The external electrode is never cut off. Furthermore, the pressure chamber plate **310**, which is made of glass, is rather strong, and thereby enables such a high polishing speed as to shorten the polishing time down to about one-fifth in comparison with conventional manufacturing methods.

The nozzle plate **330** is made of metal, e.g. stainless steel, etc. Each nozzle **332** may be formed, as described above with reference to FIG. **6**, with a punch using a pin or the like, preferably into a conic shape (or as showing a tapering section) spreading from the front surface **330**b toward the rear surface **330***a* of the nozzle plate **330**. To obtain such a conic shaped nozzle **332** is one of the reasons why the pressure chamber plate **310** and the nozzle plate **330** are not formed in one but the nozzle plate **330** is adhered to the pressure chamber plate **310**. In this embodiment, the nozzle **332** is about 80 $\mu$m in diameter at the rear surface **330***a* and about **25** through 35 $\mu$m at the front surface **330***b*. The present invention is also applicable to such an inkjet head that a nozzle thereof is formed, for example, above the pressure chamber plate **310** shown in FIG. **8**, unlike the inkjet head **300**.

On the surface (front surface) **330***b* of the nozzle plate **330**, at least around the nozzle **332**, is formed the water-repellent coating **100**. Of course, the water-repellent coating **100** may be formed all over the front surface **330***b*. The water-repellent coating serves to stabilize a wiping operation, which will be described later, and to provide a high quality image. It is to be construed that the water-repellent coating should be located differently to accompany the nozzle where the nozzle of the inkjet head is formed, for example, above the pressure chamber plate **310** shown in FIG. **8**.

In the inkjet head **300**, each external electrode **328** independently applies a voltage the internal electrode **324** of the piezo-electric block **321**, and each piezo-electric block **321** independently deforms in the direction A in FIG. **1**, bending the resin film **340** in the direction A and compressing the corresponding pressure chamber **312**. This compression results in jetting ink from the pressure chamber **321** through the corresponding nozzle **332**. When the electrification from the external electrode **328** stops, the resin film **340** and the piezo-electric block **321** returns to the original states by discharging. At that time, the internal pressure of the pressure chamber **312** reduces and ink is supplied from the common ink chamber **316** through the ink introduction channel **314** to the pressure chamber **312**.

Although this embodiment uses the piezo-electric element **320** that deforms in the longitudinal direction, but another embodiment may use one that deforms in the lateral direction. Further, the present invention is not limited to the piezo-type inkjet head employing the piezo-electric element but applicable to the bubble-type inkjet head.

Referring next to FIG. **10**, a description will be given of an inkjet printer **400** provided with the inkjet head **300** of the present invention. In each drawing, those members designated by the same reference numeral denote the same members, and a duplicate description will be omitted. FIG. **10** schematically illustrates an embodiment of the color inkjet printer (recording device) **400** to which the inkjet head **300** of the present invention is applied. In a housing **410** of the recording device **400**, a platen **414** is rotatably provided.

In a recording operation, the platen **412** is driven to intermittently rotate by a driving motor **414** and send recording paper P at a predetermined feed pitch in the arrow direction W. In the housing **416** of the recording device, a guide rod **416** is provided in parallel to and above the platen **412**.

A carriage **418** is mounted to an endless driving belt **420** that is driven by the driving motor **422** reciprocating for scanning along the platen **412**.

The carriage **412** is mounted with a black recording head **424** and a color recording head **426**. The color recording head **426** may comprises three parts. The black recording head **424** is removably provided with a black ink tank **428**, and the color recording head **426** is removably provided with color ink tanks **430**, **432** and **434**. The inkjet head **300** of the present invention is applicable to such recording heads **424** and **426**.

Needless to say, the black ink tank **428** accommodates black ink and the color ink tanks **430**, **432** and **434** accommodate yellow ink, cyan ink and magenta ink respectively.

While the carriage **418** reciprocates along the platen **412**, the black recording head **424** and the color recording head **426** are driven based on image data received from a word processor and a personal computer, etc., predetermined characters, images and the like are recorded on recording paper P. When the recording operation is suspended, the carriage **418** is returned to its home position and this home position is provided with a nozzle maintenance mechanism (or backup unit) **436**.

The nozzle maintenance mechanism **436** is provided with a movable suction cap (not shown) and a suction pump (not shown) connected to the movable suction cap. When the recording heads **224** and **226** are placed at the home position, the suction cap is adsorbed to the nozzle plate of each recording head and the nozzle of the nozzle plate is sucked. This mechanism prevents the nozzle from being plugged. After that, a wiping unit (also not shown) wipes out the nozzle plate **330***b* with a wiper. On that occasion, the water-repellent coating **100** wipes out ink on the nozzle plate surface **330***b* completely, and the hard body **108** in the water-repellent coating **100** prevents the water-repellent coating from being destroyed or otherwise.

Although the preferred embodiments of the present invention have been described above, it is to be understood that various modifications and changes may be made in the present invention without departing from the spirit and scope thereof.

According to the water-repellent coating as set forth in claim **1**, the water repellency of its fluoric polymer works well serving to provide a high quality image, and its hard body enhancing the wiping resistance of the fluoric polymer guarantees to continuously provide the high quality image. According to the water-repellent coating as set forth in claim **2**, its flat hard body is not so vulnerable to friction or likely to fall off compared with a spherical hard body, and therefore can keep its wiping resistance for a long time. According to the water-repellent coating as set forth in claim **3**, its flat body having a big particle diameter never prevents the nozzle plate surface from being smoothly wiped. According to the water-repellent coating as set forth in claims **4** and **5**, the flat hard body applicable to claim **1** is easily obtainable. The water-repellent coating as set forth in claims **6** and **7** can be easily formed without any special plating process. The recording device as set forth in claim **8** including the same water-repellent coating as claimed in claims **1** through **7** have the same effect as these claims.

The method of forming the water-repellent coating as set forth in claim **9** enables the hard body to protrude from the water-repellent coating surface; therefore, the wiping resistance of the water-repellent coating is advantageously enhanced. According to the method of forming the water-repellent coating as set forth in claim **10**, the fluoric polymer melts by the heat treatment taking in the additive hard body whereby sufficient water repellency is expected even on the surface of the intrinsically low water-repellent hard body.

What is claimed is:

**1**. A print head comprising:

a nozzle plate including a nozzle which jets ink; and

a water-repellent coating which is formed on said nozzle plate as a substrate around said nozzle and comprises a fluoric polymer formed by a plating process and a hard body protecting said fluoric polymer.

**2**. A print head according to claim **1** wherein said hard body has a flat shape.

**3**. A print head according to claim **1** wherein a major axis of a particle diameter of said hard body does not exceed 1 $\mu$m.

**4**. A print head according to claim **1** wherein said hard body includes a boron nitride single crystal.

**5**. A print head according to claim **1** wherein said hard body includes a boron carbide single crystal.

**6**. A print head according to claim **1** wherein an electrolytic plating process is adopted as said plating process.

**7**. A print head according to claim **1** wherein an electroless plating process is adopted as said plating process.

**8**. A recording device comprising:

a print head; and

a driving device which drives said print head wherein said print head includes:

a nozzle plate including a nozzle which jets ink; and

a water-repellent coating which is formed on said nozzle plate as a substrate around said nozzle and comprises a fluoric polymer formed by a plating process and a hard body protecting said fluoric polymer.

**9**. A method of forming a water-repellent coating comprising the steps of:

forming a resist onto a nozzle plate while partially projecting the resist from the nozzle outwardly;

performing a strike deposit via the resist;

performing a water-repellent coating containing a plated coating, a fluoric polumer and a hard body protecting said fluoric polymer via the resist; and

removing the resist.

**10**. A method of forming a water-repellent coating according to claim **9** further comprising the step of heating said water-repellent coating until a water repellency of said water-repellent coating becomes enough to make a contact angle of ink containing 10% of alcohol 60 degrees or larger.

* * * * *